Economics of the Sapogenin-Bearing Yam as a Crop Plant in Puerto Rico[1]

F. W. Martin, E. Cabanillas, and M. H. Gaskins[2]

INTRODUCTION

Sapogenins extracted from tubers of wild *Dioscorea* species from Mexico and Central America are the chief source of materials for preparing steroid drugs. Such drugs are widely used in treatment of many diseases, and for control of ovulation in humans and animals. Depletion of natural supplies and increasing clinical use of steroid compounds have promoted interest in cultivation of sapogenin-producing *Dioscorea* species. Field trials have shown that these may be cultivated, and their yields in response to certain cultural practices have been investigated (*1,2,3*).[3]

This paper discusses and compares cultural practices which have been studied at the Federal Experiment Station at Mayagüez, and provides cost comparisons and estimates of total production costs for growing steroid-yielding *Dioscorea*.

SOURCES OF INFORMATION

Various accessions of *Dioscorea composita* Hemsl. and *D. floribunda* Mart. & Gal. were used in the experiments which provided the information for this report. The lines used had been selected for superior growth rate and yield from a larger number of original introductions, but had not been improved by breeding procedures. Many of the basic cultural data were taken from results obtained at this Station. No attempt is made in this paper to substantiate unpublished results, but some of the supporting data will be included in later publications.

Reports of the Department of Agricultural Statistics of the Commonwealth of Puerto Rico were consulted for information on crop yields and values, agricultural wage rates, and land-lease costs. Individuals and corporations engaged in various types of farming were also solicited for information. Costs of various cultural treatments were calculated after time and motion studies. All time measurements were replicated at least 3 times. Wage rates of 60 cents per hour for hand labor and 80 cents per hour for machine operators were used in computations. The cost of tractors

[1] In cooperation with New Crops Research Branch, Crops Research Division, Agricultural Research Service, U.S. Department of Agriculture, Beltsville, Md.

[2] Plant Geneticist, Agricultural Research Technician, and Officer in Charge, respectively, Federal Experiment Station, Crops Research Division, Agricultural Research Service, U.S. Department of Agriculture, Mayagüez, P.R.

[3] Italic numbers in parentheses refer to Literature Cited, p. 64.

and other machinery was considered to be the present rental value of such equipment in Puerto Rico.

CULTURAL METHODS

The sapogenin-bearing yams grow well on a variety of soils, but best yields have been obtained on well-drained, fertile loams. Some tests have indicated that higher percentage yields may be obtained in sandy soils or soils low in fertility, but tuber growth has been retarded. More studies of the relation of soil type to yield are necessary.

Plants may be started from seed in well-drained, weed-free beds protected from climatic extremes. Seeds germinate in about 3 weeks, and seedlings require 5 or 6 months of growth in the nursery before field transplanting. Plants may also be propagated from pieces of the tuber and from single-leaf stem cuttings. When tubers are used for propagation they are treated with ethylene chlorohydrin to break dormancy, and are then planted directly in the field. Cuttings must be rooted under mist spray and well established as plants before field transplanting.

Plantings may be made by hand or by a mechanical planter. In the latter case the tubers must be essentially free of soil, and vines must be cut back to two or three nodes for easy handling. Spacing may vary considerably, but maximum yields were obtained at this Station with the closest spacing tested (1 × 4 feet). A system of drainage must be provided. At the Federal Experiment Station this has been accomplished by growing plants on raised beds or ridges.

Dioscorea plants grow slowly for the first few months after their establishment in the field, and require careful protection from weed competition. First-year cultivation costs are high because of the necessity of frequent hand-weeding operations. Herbicidal control of weeds appears feasible, but cannot be recommended until additional studies have been completed. Weed management is less difficult in the second and later years of growth, after plants reach sufficient size to inhibit weeds by shading and competition for soil moisture. The more vigorous species, *D. composita*, is less vulnerable than *D. floribunda* to weed competition.

Dioscorea vines must be supported for efficient growth. Various nonliving support systems, such as staking and pole-and-wire combinations, have been used satisfactorily. In all experiments in which they have been used, living supports such as piñon (*Jatropha curcas* L.), bucare (*Erythrina berteroana* Urban), indigo (*Indigofera sufruticosa* Mill.), and papaya (*Carica papaya* L.) have severely reduced growth and sapogenin yield.

Probably 3 years of field growth will be required before *Dioscorea* can be harvested profitably. Even 4 years in the field may prove more profitable with *D. composita*. It will be necessary to remove stakes and vines before harvesting, and these operations will probably have to be performed by hand. Mechanical harvesting methods have not yet been studied thoroughly, but tests have demonstrated that lister bottom plows may be used to plow out the tubers. After plowing, tubers can be gathered by hand, but machines to sort tubers from the soil probably can be developed. Sweetpotato- or potato-harvesting machines may be adaptable for *Dioscorea* harvesting. Heavier equipment and deeper plowing will be necessary with *D. composita* than with *D. floribunda*.

There are no marketing facilities in Puerto Rico for *Dioscorea* tubers at this time, but the active market demand for steroid precursors suggests that washed, chopped, and sun-dried tubers could be sold without difficulty to processors in the continental United States. Fresh tubers can be sold directly to processors if a plant is located near the production area, but if tubers must be shipped long distances, drying must be anticipated to prevent spoilage in transit and to reduce shipping costs.

PRODUCTION COSTS

PROPAGATION

The operations involved in the three methods of propagation vary considerably. The most rapid method of establishing new plantations is by planting tuber-pieces directly into the field after fumigation to induce sprouting. This procedure reduces the use of hand labor, eliminates the need for nursery facilities, and has the advantage of producing vigorous plants rapidly. The disadvantages of the method are that part of the marketable crop must be sacrificed, and that techniques to prevent rotting of the seed-pieces are not thoroughly reliable. The simplest method of producing large numbers of plants is from seed, but 5 or 6 months are required for seedlings to grow sufficiently large for field-planting. The most complicated method of propagation is from single-leaf stem-cuttings. This technique may have most applicability in the rapid multiplication of desirable clones for later propagation by tuber-pieces. For estimated costs of these operations see table 1.

ESTABLISHING A FIELD

Although field-preparation costs for plowing, disking, and ridging would be similar for all three types of propagules, the different materials will have to be handled differently and planting costs will not be the same (table 2). The vines of seedlings can be cut back to a foot or less and the plants then handled in a mechanical, tractor-pulled transplanter. Tuber-pieces and potted or banded plants from leaf-cuttings can be planted with the aid of simple cultivating equipment arranged to open and close the planting

furrows. However, the estimates reported herein are based on planting by hand labor.

Pre-emergence herbicide treatments to reduce weed competition during the early growth of the plant have not yet been worked out, but an expected cost has been computed from data on other crops. The individual farmer will have to manage his staking or support in accordance with locally available materials, but costs herein were calculated on the basis of buying 8-foot poles grown locally, setting these in the field, stringing them across the top with one strand of 8-gage galvanized wire, and tying nylon strings from the wire to each plant.

TABLE 1.—*Estimated costs per acre (in dollars) of production of* **Dioscorea** *plants by 3 methods of propagation*

Operations	Cost for indicated propagation material		
	Seeds	Stem	Tubers
Gathering	0.60	7.20	8.10
Cleaning	.60	—	13.00
Cutting and dividing	—	24.00	26.00
Rental of bed	9.00	43.20	—
Seeding	4.00	12.00	—
Transplanting	—	16.10	—
Maintenance	16.20	9.00	—
Digging for field	2.40	1.80	
Market value of tuber	—	—	65.00
Total	32.80	113.20	112.10

TABLE 2.—*Estimated costs per acre (in dollars) of planting and and staking a* **Dioscorea** *field*

Operation	Cost for plant sources indicated		
	Seeds	Stems	Tubers
Rental of land	40.00	40.00	40
Soil preparation	15.00	15.00	15
Transportation of plants	1.20	3.50	2
Transplanting	60.00	126.00	80
Herbicide	25.00	25.00	25
Staking	270.00	270.00	270
Total	411.20	479.50	432

CULTIVATION, MAINTENANCE, FERTILIZATION, AND PEST CONTROL

Once established in the field the two species of *Dioscorea*, from whatever source of propagation material, will require approximately the same amount of maintenance and care. During the first year when plants are small, weeding will have to be done more frequently than in following years. On the other hand, the staking system will require very little maintenance the first year, but regular maintenance thereafter. Costs were estimated (table 3) for weeding with an oxen-pulled shallow cultivator; for fertilization on the basis of 1,000 pounds per year of a balanced mixture; for insect control on the basis of two treatments per year of a systemic insecticide, and for leaf-fungus control, one treatment per year. Maintenance of stakes will depend on type of material used and whether it is treated to prevent termites and rotting.

TABLE 3.—*Estimated costs per acre per year (in dollars) of cultivation and maintenance of a* **Dioscorea** *plantation*

Operation	Cost for —	
	First year	Later years
Weeding in rows	32.50	21.50
Fertilization	37.50	37.50
Insect control	17.00	17.00
Fungus control	15.00	15.00
Staking maintenance	—	25.00
Total	102.00	116.00

HARVEST

Until techniques are perfected, harvest operations will be expensive, and accurate estimates of costs cannot be made. The first step in such an operation will be cleanup of the field. Strings and vines can be cut and wires removed and rolled up for future use. The labor involved will depend on the density of the vine growth and age of the plants. The posts can be knocked over by a bulldozer or large tractor and the vines and poles raked or carried away. Plowing of the field will then take very little time, and the exposed tubers can be gathered by hand and carried in boxes to trucks or trailers.

Satisfactory systems of washing and drying will have to be developed, but this should not be a serious obstacle. The estimates in table 4 were based upon the assumptions that, after the furrows are opened by machine, the tubers will be picked up by hand, and that tubers then be washed with

a high-pressure pump, chopped with a beet or silage chopping machine, and sun-dried on a paved surface or in drying shed, such as is used for drying coffee. The cost of the equipment is included in the estimate of the cost of the washing, chopping and drying operations. Hauling and marketing costs were not calculated herein.

SUMMARY OF PRODUCTION COSTS

Total costs will be determined by the species used, the method of propagation, and the age of the tuber at harvest (table 5). Costs may differ from those anticipated, depending on the local availability of supplies, the prevailing wage rates and the availability of special equipment. Most operations should be suitable for a high level of mechanization, but unless large-scale operations are anticipated, some equipment may not be justified.

TABLE 4.—*Estimated costs per acre (in dollars) of harvesting* **Dioscorea** *plantations of various ages*

Operation	Costs for species indicated					
	D. floribunda			*D. composita*		
	2 yr.	3 yr.	4 yr.	2 yr.	3 yr.	4 yr.
Removal of support	20	22	22.00	24	28	28
Removal of vines	8	10	11.00	10	14	16
Digging	12	15	17.00	15	20	23
Gathering and loading	16	25	34.50	20	30	42
Washing, chopping, and drying	20	24	28.00	25	30	40
Total	76	96	112.50	94	122	149

YIELDS

For purposes of estimating gross income, yields have been averaged for the various soils and cultural treatments used with *Dioscorea* at Mayagüez. It is recognized that these variables may have profound effects on yields, but optimum soil drainage, fertilizer, and pesticide treatments have not yet been determined. Yields are also related to age of tuber and to species, both of which have been taken into account in calculating gross income (table 6). Finally, yields are related to source of propagating material, but data are not extensive enough to clarify all of these relations.

Dioscorea tuber is purchased on a dry-weight basis. Current market value is about $250 per ton of air-dried tuber of about 4-percent sapogenin content. The added quality of tuber from a single species would result in a higher market price. Consequently $275 per ton has been selected as an estimated basic price of dried tuber of 4-percent of sapogenin content. Prices of tubers of higher and lower sapogenin concentrations have been calculated as appropriate proportions of this figure (table 7).

PROFITS

Estimated profits have been calculated based on yields actually obtained at Mayagüez, and costs as estimated herein. Certain trends are evident in table 8. First, the crop cannot be harvested profitably before the third year. Available data suggest that potential profits would increase after the third year. Second, estimated profits from plants grown from seed are lower at all ages than profits from plants grown from tubers. Starting plants from tubers appears to provide about a year's advantage in terms of rate of growth and final yield, even after subtracting part of the yield which would be needed for replanting. Unfortunately, very few yield data from plants propagated by stem cuttings are available, but it would appear that such plants are more readily established and grow more rapidly than seedlings, but do not grow as rapidly, or yield as well as plants from tuber cuttings. Nevertheless, the stem-cutting technique offers advantages in

TABLE 5.—*Summary of* **Dioscorea** *tuber production costs per acre (in dollars)*

Species	Age at harvest (years)	Source of plants	Costs for phases of production indicated				
			Propagation	Planting	Maintenance	Harvest	Total
D. floribunda	2	Seeds	32.80	411.20	218	76.00	738.00
	2	Stems	113.30	479.50	218	76.00	886.80
	2	Tubers	112.10	432.00	218	76.00	838.10
	3	Seeds	32.80	411.20	334	96.00	874.00
	3	Stems	113.30	479.50	334	96.00	1,022.80
	3	Tubers	112.10	432.00	334	96.00	974.10
	4	Seeds	32.80	411.20	450	112.50	1,006.50
	4	Stems	113.30	479.50	450	112.50	1,155.30
	4	Tubers	112.10	432.00	450	112.50	1,106.60
D. composita	2	Seeds	32.80	411.20	218	94.00	756.00
	2	Stems	113.30	479.50	218	94.00	904.80
	2	Tubers	112.10	432.00	218	94.00	856.10
	3	Seeds	32.80	411.20	334	122.00	900.00
	3	Stems	113.30	479.50	334	122.00	1,048.80
	3	Tubers	112.10	432.00	334	122.00	1,000.18
	4	Seeds	32.80	411.20	450	149.00	1,043.00
	4	Stems	113.30	479.50	450	149.00	1,191.80
	4	Tubers	112.10	432.00	450	149.00	1,143.10

TABLE 6.—*Yields of sapogenin obtained from* **Dioscorea** *at Mayagüez*

Species	Age	Soil type	Method of propagation[1]	Total yield per acre			Mean yield sapogenin per year
				Dry matter	Sapogenin		
	Years			*Pounds*	*Percent*	*Pounds*	*Pounds*
D. floribunda	2	Catalina clay	S	2,095	4.8	101	55
	2	Nipe clay	T	4,790	6.3	310	155
	2	do.	C	3,930	4.9	193	96
	3	Toa silty loam	T	13,600	5.3	726	242
	3	Catalina clay	S	3,720	5.4	204	68
	4	do.	S	6,430	5.4	346	86
	4	Nipe clay	T	9,250	7.9	730	162
	5	Toa silty loam	T	15,520	5.2	697	139
D. composita	2	do.	T	6,940	1.3	93	46
	2	Cialitos clay	S	3,240	3.3	107	55
	2½	Catalina clay	S	6,455	3.5	226	90
	3	Toa silty loam	T	21,640	4.5	960	320
	3	Cialitos clay	S	15,730	3.7	587	196
	3	do.	S	7,260	3.9	284	95
	3	Nipe clay	T	21,300	4.6	988	329
	3½	Cialitos clay	S	20,350	4.1	840	240
	3½	do.	S	13,880	4.4	644	184
	4	Catalina clay	S	14,390	4.7	628	132

[1] S = seed; T = tuber; C = cutting.

TABLE 7.—*Average dry weights, percentage of sapogenins, and values of* **Dioscorea** *tubers after 2, 3, and 4 years of field growth*

Species	Age at harvest	Source of plants	Dry weight	Sapogenin	Value/ton	Gross value
	Years		*Pounds*	*Percent*	*Dollars*	*Dollars*
D. floribunda	2	Seeds	2,095	4.8	330	346
	2	Stems	3,930	4.9	337	662
	2	Tubers	3,415	6.3	433	739
	3	Seeds	3,720	5.4	371	690
	3	Tubers	12,225	5.3	364	2,225
	4	Seeds	6,430	5.4	371	1,194
	4	Tubers	7,875	7.9	543	2,138
D. composita	2	Seeds	3,240	3.3	226	366
	2	Tubers	5,525	1.3	89	246
	3	Seeds	11,495	4.2	289	1,661
	3	Tubers	20,095	4.5	309	3,105
	4	Seeds	14,390	4.7	323	2,324

that high-yielding clones can be multiplied rapidly without destruction of tuber materials.

COMPARISONS WITH OTHER CROPS

Figures on gross and net income from three principal crops of Puerto Rico were obtained through the courtesy of Sr. Raúl J. Tous of the Bureau of Agricultural Statistics for the year 1961–62. These figures are probably realistic except for the sugar figures, which are much lower than profits

TABLE 8.—*Total and percentage profits expected from* **Dioscorea floribunda** *and* **D. composita** *crops harvested at 2, 3, and 4 years of age*

Species	Age at harvest	Source of plants	Gross value	Production cost	Total profit or loss	Return or loss
	Years		*Dollars*	*Dollars*	*Dollars*	*Percent*
D. floribunda	2	Seeds	346	738	−392	−47
	2	Stems	662	887	−225	−25
	2	Tubers	739	838	−99	−12
	3	Seeds	690	874	−184	−21
	3	Stems	—	1,023	—	
	3	Tubers	2,225	974	1,251	128
	4	Seeds	1,193	1,006	187	19
	4	Stems	—	1,155	—	
	4	Tubers	2,138	1,107	1,031	93
D. composita	2	Seeds	366	756	−390	−52
	2	Stems	—	905	—	
	2	Tubers	246	856	−610	−74
	3	Seeds	1,661	900	661	85
	3	Tubers	3,105	1,000	2,105	210
	4	Seeds	2,324	1,043	1,281	122
	4	Stems	—	1,192		
	4	Tubers		1,143		

have been during the last two seasons. Nevertheless, these figures can be compared with some accuracy with those from *Dioscorea* (table 9). Estimated profits from *Dioscorea* after 3 or 4 years were quite high in comparison to profits from local crops. In most cases, errors in estimated costs of even $100 per acre per year would still allow comfortable profit margins.

DISCUSSION

The constant increase in demand for steroidal drugs and the fact that *Dioscorea* tuber is the least expensive source of the raw materials used in the synthesis of these drugs have suggested the possibility of growing *Dioscorea* on a commercial basis. Unfortunately, there is no market for the

tubers in Puerto Rico, and until one develops, the wild yams cannot be recommended as a crop. Shipping costs to a distant market were not calculated herein, but could add considerably to total costs. Nevertheless, studies of the type reported here may encourage the eventual development of the industry.

Although based on small-scale field plots, and thus subject to error when extrapolated, these observations and calculations suggest that *Dioscorea* may well compete with the three chief crops of the Island in terms of estimated net income per acre and interest on investment. Nevertheless, there are several reasons why the rapid development of the industry should not be anticipated.

TABLE 9.—*A comparison of mean estimated income per year per acre from 2* **Dioscorea** *species and 3 principal crops of Puerto Rico*

Crop	Gross income	Operating costs	Profit	
	Dollars	*Dollars*	*Dollars*	*Percent*
Tobacco	517	374	143	38
Sugar	346	323	23	7
Coffee	121	101	20	20
Dioscorea, 3-year basis:				
D. floribunda tubers	741	325	416	128
D. composita seedlings	554	300	224	75
D. composita tubers	1,035	333	702	211
Dioscorea, 4-year basis:				
D. floribunda seedlings	298	252	46	18
D. floribunda tubers	534	277	257	93
D. composita seedlings	581	261	320	122

First, the high costs of establishing the *Dioscorea* plantation must be borne for at least 3 years before a crop is ready for harvest.

Second, growing *Dioscorea* will be a fairly complex task necessitating careful planning of unusual farming and marketing procedures. A certain amount of improvisation will be necessary and special equipment may have to be built or imported.

Third, in the absence of extensive, successful production of medicinal *Dioscorea* in the past, high risks will be involved. It is possible that unfavorable growth may occur in some soils or under some climatic conditions. Labor costs might be higher than estimated. It is possible that disease problems might become serious obstacles in large plantings. Virus and fungus diseases found in *Dioscorea* plantings are under investigation at the Federal Station. The importance of these diseases has not yet been determined. A full investigation of the risks involved in *Dioscorea* production

cannot be obtained entirely from experimental plantings. The evaluation of any new crop must eventually include a commercial venture on a scale larger than that practical in experimental investigations.

In the interest of stimulating public interest in the sapogenin-bearing yam and testing materials under contrasting conditions, this Station, in cooperation with the Agricultural Experiment Station of the University of Puerto Rico, has established three acre-sized plantings of two species, *D. floribunda* and *D. composita*. These plantings are located at Isabela, Corozal, and Adjuntas. It is anticipated that seed and clonal material of the better varieties will be maintained at the Federal Experiment Station, and as conditions warrant, will be made available to local farmers or others who have a serious interest in growing this crop plant.

SUMMARY

From experiments at the Federal Experiment Station, Mayagüez, data on costs in Puerto Rico, and other estimates an analysis of the costs of production and potential profits in the growing of *Dioscorea* were recorded and calculated. The analysis was divided into costs of producing plants, establishing a plantation, yearly maintenance, and harvest. Values and profits were calculated on the basis of species, yields, ages, and sapogenin contents.

The chief suggestions to be made as a result of the study were: That initial costs would be heavy and almost prohibitive; that the greatest single expense would be the cost of staking; that profits would not be possible within less than 3 years of field growth; that profits would increase during the fourth year; that *D. composita* could be grown more profitably than *D. floribunda;* and that plantations established from tuber-pieces would be more profitable than plantations established from seed. Provided no serious pest or disease destroys the plantings, it is concluded that *Dioscorea* could compete favorably with certain presently existing crops in Puerto Rico.

RESUMEN

En la Estación Experimental Federal, en Mayagüez, se hizo un estudio sobre el costo de producir ñames silvestres de los que se usan como fuente para la sapogenina. El estudio incluyó el costo de producir las plantas, sembrarlas en el campo, y mantenimiento y cosecha de los tubérculos. También se discutieron los métodos de siembra que se aplican, los materiales que se usan y la mano de obra. Se estimaron los costos de producción a base de especies, rendimiento, edad y contenido de sapogenina.

El estudio destacó lo siguiente:

1. Los costos iniciales resultaron muy altos y casi prohibitivos.

2. La faena más costosa fue la de estacar las plantas.

3. Sería imposible obtener beneficios de plantaciones de menos de 3 años de sembradas.

4. Los beneficios suelen aumentar a los 4 años.

5. La *Dioscorea composita* puede producir más beneficios que la *D. floribunda*.

6. Las plantaciones sembradas con pedazos de tubérculos dan mayores beneficios que las sembradas de semilla.

Como conclusión final puede decirse que, de no aparecer enfermedades o insectos, el género *Dioscorea* puede competir favorablemente con las otras cosechas comerciales de Puerto Rico.

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